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IDENTIFICATION OF TARGET CONCEPTS AS A FUNCTION OF INFORMATION LOAD

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WRIGHT AIR DEVELOPMENT CENTER

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FOREWORD

This report was prepared by the University of Wisconsin under Contract No. AF 18(600)-54. The contract was initiated under a project identified by Research and Development Order 694-49, "Human Engineering Research on Fire Control and Missile Control Systems." The contract was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center with John W. Senders acting as Project Engineer.

ABSTRACT

Twelve groups of six Ss each served in an experiment on target identification. The groups corresponded to the cells of a 3 x 4 factorial design having 1 to 4 bits of relevant information and 0 to 2 bits of irrelevant information, presented to S by a single stimulus source. The S's task was to identify oscilloscope patterns by positioning four lever-action switches and testing his identification by pressing a push-button. The response measure was the time required to identify 32 consecutive patterns. Errors were also recorded but they did not vary as a function of any parameter except practice. The major findings were (a) time to respond increases as a linear function of relevant information load, but (b) was independent of amount of irrelevant information. These results were related to previous studies and differences considered.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

INTRODUCTION

Much of behavior is directed by the information an organism receives. Quite often more information is received than can be effectively used either because the organism cannot assimilate all of the relevant information or because some of it is irrelevant to the organism's behavior. In a simple example, a traffic sign bearing the word "STOP" transmits a certain amount of information which is relevant to the behavior of an automobile driver. The size, color, brightness, location and even shape are irrelevant. Except for their constancy and consequent redundancy these last named attributes of the sign do not increase the presented information although they may increase the amount transmitted. When redundant, irrelevant information may increase information transmission, but when not redundant, information transmission will not be increased and may even be degraded. A study by Miller (4) which compared simple and complex conditional stimuli suggests that redundancy may increase information transmission even in a relatively simple communicative event. More conditioning occurred with two conditional stimuli than with either alone. From simple discrimination problems to concept formation tasks, one of the primary needs of S is to identify the relevant information provided by the stimulus. The amounts of relevant and irrelevant information in a stimulus may vary independently of each other and task complexity is a function of amount of either or both types of information.

In a simple discrimination problem, Gregg (3) has shown that reaction time to visual stimuli increases as amount of irrelevant information increases. In his study, Ss were required to move a joy stick either left or right depending upon the position, size, or brightness of a single dot on a dark field. Reaction time was longer as the irrelevant information was increased.

In a slightly more complex task, Archer and Bourne (1) have found that time to solution of a concept formation problem increased as amount of irrelevant information increased. In this case, however, it may be suspected that S would attempt to incorporate the irrelevant information into hypotheses about the proper solution of the task and thereby be delayed since, by definition, irrelevant information could not enter into the correct solution of the concepts.

In Gregg's study, S had but one response to make and this was to one bit of relevant information. The effect of increasing amounts of irrelevant information was non-linear because of the factor of stimulus-response compatibility.

In the Archer-Bourne study the effect of irrelevant information was non-linear since S did not know what information was irrelevant until tested, and for each additional bit of irrelevant information added the number of necessary tests doubled. It is conceivable, and in fact likely in view of Gregg's results, that irrelevant information may slow down S without actually being tested in a hypothesis. Furthermore, it is possible that there would be an interaction between amount of relevant and irrelevant information. Two predictions which might be made are that the amount of irrelevant information not only increases reaction time but will show an even greater effect as the amount of relevant information increases.

The present study was designed to test these hypotheses. Ss saw patterns on an oscilloscope screen and classified those on four dimensions. Some dimensions were constant and contributed no information. Other dimensions varied between two levels, randomly and equally often. When one of the four classifying switches corresponded to this variable stimulus the information was relevant. When a switch was not available the information was irrelevant. The primary response measure was total time in minutes to classify the 32 patterns.

PROCEDURE

Subjects. Seventy-two paid male students at the University of Wisconsin served in this study. Each S was assigned randomly to one of 12 conditions and served for but one day for about 40 minutes.

Apparatus. A device designated as a Target-Concept Identification Apparatus was used. It consists of a cathode ray oscilloscope, the S's control unit which has four lever-action switches and a push-button, a pattern generator, and a recording console. The pattern generator, which is connected by electrical cables to the oscilloscope and S's control unit, is operated by E through the use of two Western Union tape transmitters which program the patterns presented to S. The patterns are presented on the oscilloscope and may be classified according to one of two levels on each of six dimensions. These dimensions are form (circle or ellipse), size (small or large), brightness (bright or dim), speed (fast or slow), vertical direction (up or down), and horizontal direction (right or left). Since all patterns in this study travelled on a 45° or 315° diagonal, each had horizontal and vertical components. Since S's control unit had only four lever-action switches, only four of the six dimensions could be classified by S. The pattern generator had interchangeable leads which permitted a selection of the particular dimensions to be classified. The S's control unit had interchangeable markers which signified the functional positions of the four lever-action switches. When the pattern generator was wired for a particular series of patterns, the Ss control unit was modified accordingly.

The recording console had two counters, a Standard Electric clock (0.01 minutes scale) and a program-starting button. After S was given a "ready" signal, the program-starting button was pressed. This action simultaneously presented the first pattern to be classified and started the timer clock. One of the counters recorded correct responses and the other recorded errors. When 32 patterns had been classified, the clock automatically stopped and S received a signal to stop working. Each S was instructed in the operation of the control unit as well as how to identify the levels of all dimensions. When a pattern was presented, he was to position each of the four lever-action switches according to the levels of each of the four dimensions for which he had switches and then press the push-button. If, for example, the control unit had switches for speed, size, form, and horizontal direction and a small, bright, fast, circle moved from upper left to lower right, S would have to identify the speed as fast or slow and move the switch with these markers to one or the other position. He would have to do the same for each of the other dimensions of size, form, and horizontal direction. After all switches had been positioned (they always returned to center after firing holding relays) S would press the push-button. If his identification and positioning were correct, a green panel lamp would light. If he were wrong, a red panel lamp would light. In both cases, however, a new pattern was presented. Whenever the push-button was fired, all holding relays were released which required S to reposition all four switches again even if successive patterns were the same.

It was possible to have from zero to six of the dimensions vary within a particular series. Since each dimension could only vary between two levels, it was possible to present series having 0, 2, 4, 8, 16, 32, and 64 different patterns. The first of these, 0 different, is of no interest to our problem. If a dimension is not varied no information is presented. If a dimension is varied and no switch for classifying it is available, then the information is irrelevant. If a dimension is varied and a switch is available then the information presented is relevant.

Both levels of all dimensions were easily discriminated and Ss were instructed as to essential identifying cues.

Design. Within the limitations of the apparatus, a 3 x 4 factorial design was used. Three levels of irrelevant information were orthogonal to four levels of relevant information. Six Ss served under each of these 12 relevant-irrelevant conditions. Each S classified 32 patterns as quickly as possible and then had a one minute rest. This cycle was repeated six times for a total of 196 classifications. To reduce the likelihood of a particular combination of dimensions being unusually easy or difficult, a different combination of relevant and irrelevant dimensions was used for each S. This would mean, for example, that in the two relevant-one irrelevant conditions, one S had size and brightness relevant and form irrelevant whereas another S had form and speed relevant and vertical direction irrelevant.

General. All Ss were given tape-recorded instructions which stated they had to position all four switches and press the push-button as fast as possible. They were told to use one hand for the lever switches and one for the push-button. Furthermore, they were instructed to never move more than one switch at a time and never to move a switch before a pattern was presented, no matter how unchanging the patterns might be. After the instructions all of the 64 possible patterns were presented until S could give evidence of verbally identifying each of the two levels of the six dimensions of every pattern. For some dimensions there was an absolute basis for judgment, e.g., form and direction. For brightness, speed, and size, since the two levels of these dimensions were relative, S had to memorize cues, e.g., the dim patterns were just barely visible whereas the bright ones caused the entire oscilloscope to glow with a green light. During the demonstration S was prevented from practicing moving the switches and the emphasis was placed on verbal identification.

The importance of speed was stressed, but S was also cautioned to get as many right as possible. S was further instructed as to the purpose of the red and green panel lamps before him as well as the cease working signal which was a bright white light which was lit during the one minute inter-trial rest periods.

RESULTS

Response Time. The dependent variable of major interest in this study was the time required by S to classify the series of 32 patterns. The mean response times for each of the 12 conditions of amount of relevant and irrelevant information is presented in Table 1. Although there are a few small

TABLE I

Mean Response Times (Minutes) for Each of the Relevant-Irrelevant Conditions.

		Bits Relevant Information				
	-----	1	2	3	4	Mean Total
Bits Irrelevant Information	0	2.24	2.47	3.15	3.08	2.73
	1	2.12	2.99	2.85	3.65	2.90
	2	2.34	2.69	3.37	3.30	2.93
	Mean Total	2.24	2.72	3.13	3.34	-----

reversals of trends within particular rows and columns, these were not significant. The differences among the row means (three levels of amount of irrelevant information) were also not significant but the differences among the columns means (four levels of relevant information) were highly significant. All of these tests of significance are shown in Table 2. As may also be seen there was a significant variation attributable to individual differences as well as to practice.

TABLE II

Analysis of Variance of Response Times (Minutes) Required to Classify 32 Patterns.

Source	df	MS	F
Relevant	3	25.65	17.74*
1. Linear	1	74.97	51.70*
2. Quadratic	1	1.89	1.30
3. Cubic	1	0.08	-----
Irrelevant	2	1.59	1.10
Relevant x Irrelevant	6	2.30	1.59
Ss / Groups	60	1.45	9.28*
Trials	5	37.65	241.47*
Trials x Relevant	15	0.17	1.07
Trials x Irrelevant	10	0.29	1.84
Trials x Relevant x Irrelevant	30	0.16	1.01
Ss x Trials / Groups	300	0.16	
Total	431		

*$p < 0.001$

The effect of practice on time to classify the patterns is shown in Fig. 1 for the relevant information, summed across the three levels of irrelevant information, and Fig. 2 for the irrelevant information, summed across the four levels of relevant information. Two effects are immediately apparent: (a) with practice the time to classify the series of patterns decreases, and (b) only the curves based on the classification of relevant information show a relationship between time and the information measure of the stimulus. Both of these effects are highly significant as shown in Table 2.

The relationship between time to respond and amount of irrelevant information, as a function of practice, appears to be clearly negligible. From Table 2 there was a suggestion that the Trials x Irrelevant information interaction might be significant. An F-ratio of 1.836 was found and for 10 and 300 df an F-ratio of 1.86 is necessary at the .05 level of confidence. Furthermore, from Fig. 2 it appeared as if all three curves were converging and that there might be a difference in rate of classification as a function of irrelevant information early in learning only. An analysis of variance of time scores on the first trial indicated this hypothesis was untenable ($F = 1.166$, $p > 0.05$, 2 and 60 df).

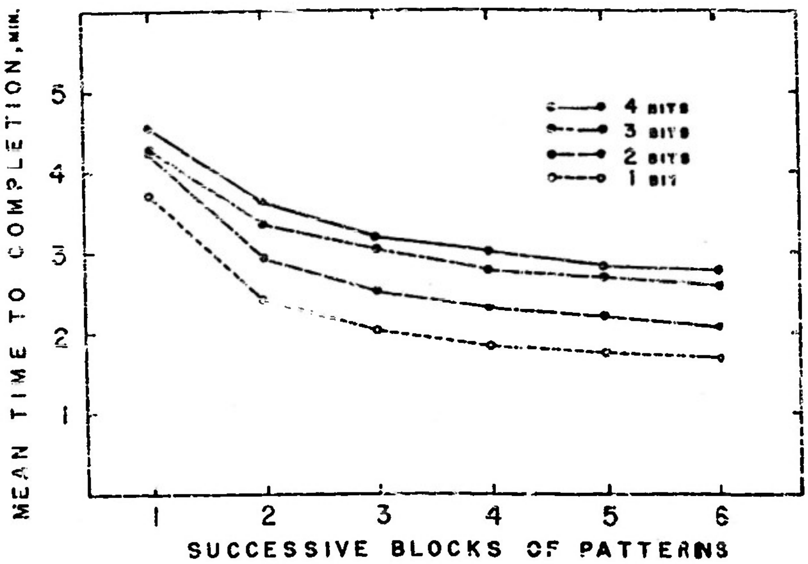

Fig. 1. Mean response time in minutes per block of 32 consecutive patterns as a function of stage of practice and amount of relevant information.

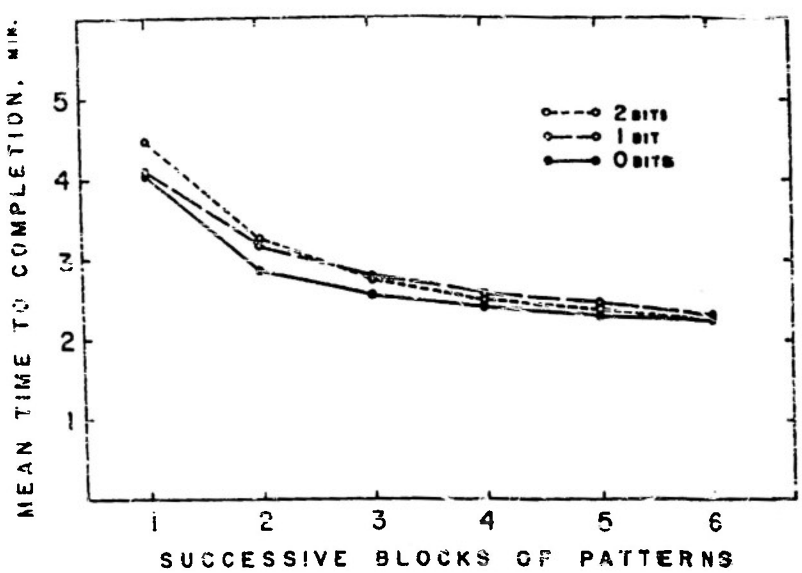

Fig. 2. Mean response time in minutes per block of 32 consecutive patterns as a function of stage of practice and amount of irrelevant information.

A final point of note was the orderly increase in response time required as the number of relevant bits increased. This relationship is apparent in Fig. 1. A test of this trend was made through the use of orthogonal polynomials (2). For the four points of a curve plotted with relevant bits presented against response time, we have three df; one each for a linear, quadratic, and cubic component. The results of this analysis are also shown in Table 2 in which the Relevant (between groups) sums of squares is partitioned into these three components and tested against the Ss/Groups error term. Only the linear component was significant which indicates that as the amount of information to which S must respond increases, the time required also increases as a linear function. The best fitting equation for this line was determined during the polynomial solution and was found to be $Y = 0.372X + 1.925$.

Errors. Another response measure which was obtained was number of errors made in responding to the 32 patterns. An error was automatically recorded if S pressed the push-button before he had positioned all four switches or if he positioned one of them incorrectly. Even if more than one was incorrectly positioned, only one error was recorded. There was no systematic variation in errors except to decrease with trials. ($F = 223.34$, $p < .001$, 5 and 300 df). No variation in number of errors appeared as either of the other two main effects were manipulated.

DISCUSSION

A study by Gregg (3) indicated that the reaction time to a single stimulus increases as amount of irrelevant information associated with the stimulus increases. His measure in 0.01 second units was the time between the presentation of a single stimulus and its response. In all cases his Ss responded to but one relevant bit of information and had from zero to three bits irrelevant.

In the present study, 32 patterns were presented at a self-paced rate, i.e., a new pattern appeared after S responded to the previous one, and the response time was the total elapsed time from the presentation of the first pattern until the response to the thirty-second pattern. The Ss in this study were presented with patterns having from one to four bits relevant and from zero to two bits irrelevant information. To assure that the number of physical responses would be the same for all groups, Ss were required to position all four switches and then press the push-button for every pattern classification. This was true even if three of the switches always were correct in the same position, e.g., those patterns having but one bit relevant. In a sense, the number of relevant bits of information determined the number of decisions that S had to make about a stimulus. If all patterns that a particular S saw were small, bright circles but some went to the left and others to the right, the only decision S had to make would be with respect to direction.

Although it may seem reasonable to assume there were two components to the responses, (a) the motor response of moving a switch, and (b) the more mentalistic response of deciding in which position to move it, there was no evidence for this dichtomy, or at least if such did exist, practice facilitated both equally well. If this were not the case, the learning curves in Fig. 1 would not have been parallel. Since, if practice facilitated performance of one type of response more than another the curves would have diverged.

It appears unlikely that the different procedure for measuring response time used in the present study would account for the lack of agreement with the Gregg study. More likely, it seems, the differences can be ascribed to the response requirements. Gregg first trained his Ss to respond to patterns which varied in one dimension only. Then in a second stage of the study, irrelevant information was introduced and the degradation of reaction time was observed. The Ss never had to make a response to more than one relevant dimension. In the present study, Ss always had to respond to four dimensions of the stimulus, some of which varied. Unlike the Gregg study, they also learned, before the first trial, all the possible patterns which could occur.

There are two findings of the present study which have significance for any theories of information transmission from a single stimulus source: (a) the amount of time required to decode and respond to information increases as a linear function of the amount of relevant information presented, at least up to four bits; and (b) response time appears to be unaffected by variations in information load as a function of amount of irrelevant information, at least up to two bits. The data also indicate that practice will improve performance in speed of pattern identification but this effect is independent of amount of information load.

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